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Study of inhibition characteristic of sand suspending thickener for spontaneous combustion prevention

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Abstract

In order to investigate the inhibition characteristics of green and environmentally friendly sand suspending thickener, we applied the self-designed Temperature Program Experiment System to test three different inhibiting substances, the calcium chloride, the soluble glass, and the sand suspending thicker, for comparison. Comparing the oxidation temperature curves of the primordial coal with the ones processed by inhibiting substances, we found that the temperatures of processed coals were all quite low and the temperature of the coal processed by sand suspending thickener the lowest. Therefore, the sand suspending thickener is the best material among the tested materials for fire-fighting in coal mine.

Keywords: the sand suspending thickener; inhibition characteristic; inhibiting substance; Temperature Program Experiment System

1. Introduction

The coalfield of Shengdong coal mining area, the largest reserve coalfield now, is abundant in reserves and the excellent in quality of the coal. But all the coal seams are easily spontaneously combusted, making the fire preventing work much difficult. The technology of conventional slurry injecting is difficult to put into practice for the lack of loess and water in the mining area, whereas there is abundant sand which can be used for the slurry material for preventing fire. But the technology of the conventional sand slurry injecting needs a lot of water with the water/sand 7 ratio of t~11 to ensure the sand not to subside [1-3]. And the severe abrasion of the pipeline and the sand dehydrating may break the underground surroundings. For the special conditions of the mining area, the sand suspending thickener of type KDC [4-8] adopted in the mining area is invented under the cooperation of the Institution of Mine Ventilation and Fire Preventing in China University and Mining and Technology (CUMT) and the Group of the Shenghua. The thickened sand grout which is combined by the thickener has a perfect performance for preventing fire. In the practical use of this technique in Daliuta and Bulianta coal mines, the volume ratio of the thickened sand grout of water and the sand is about 7:3, and the grout can suspend plenty of sand which is used to cover on the coal in the form of fluid. The technology can conquer the shortage of fire preventing capability caused

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by the gelatin dehydration.

Because of the covering ability of sand and grout and the decalescence of the grout, the sand suspending thickener of type KDC has a significant effect on the fire preventing. However, due to the deficient in research on inhibition characteristic, our study aims at the inhibition characteristic of the sand suspending thickener.

2. Materials and methods

2.1. Mechanism of inhibiting substance for coal spontaneous combustion

The inhibiting effects of inhibiting substance for the incompact coal or the coal seam are listed as follows [6]:

Inhibiting substance can isolates coal from oxygen by covering on the surface of coal and accelerate the thermal dissipating while water keeps the coal wet. Additionally, the inhibiting substance, also a kind of chemistry element, can join in the free radicals chain reaction and create some stable chains (by substitution reaction and complex reaction). This process increases the Activation Energy of the chemical reaction between the free radicals and the oxygen on the coal surface and controls the reaction velocity so that the inhibiting substance can abate the coal spontaneous combustion.

2.2. Experiment system and the method

The method of the inhibiting rate E is the evaluating index of the performance of the inhibiting substance in laboratory which is defined as:

$$E=CO_i/CO_o \quad (1)$$

where CO_i is the CO emanating differences in the oxidation of coal pre- and post-treatment by inhibiting substances; CO_o is the percentage of CO emanating from the coal oxidation without treated by inhibiting substances. In this definition of the inhibiting rate E, 100 °C is not appropriate for the testing standard temperature [9] because in aerobic environment of 100 °C, the output of CO in coal oxidation is increased unsteadily; moreover, there are different inhibition mechanisms at different temperatures and stages, and there are also different inhibiting effects for the coal spontaneous combustion during the whole oxidation process.

The testing method for inhibition characteristic based on temperature programmed experiment is put forward by the Institution of Mine Ventilation and Fire Preventing in CUMT using the self-designed experiment system [9-10]. We use the experiment system and the method to test the inhibition characteristic of the sand suspending thickener of type KDC.

The experiment system, shown in Fig. 1, includes adiabatic oxidation equipment which can minimize the heat loss and the data acquisition system can acquire the real time temperature of the coal sample.

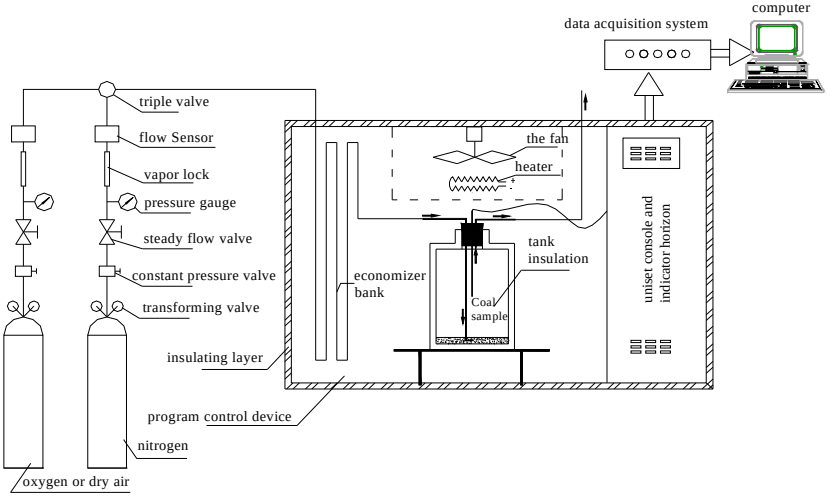

Fig. 1. System of simulating spontaneous combustion of coal using adiabatic oxidation equipment

2.3. Preparing the coal samples

In the experiment, we selected the fresh coal sample of the fully mechanized sub-level caving face No. 3105 in Jinzhuanshengjian coal mine. Coal samples collected were 260 g in weight, crashing and separating to 40~80 mesh at about 35 °C. At last the sample was divided into 4 parts with 50 g for each.

We chose the calcium chloride, soluble glass and the sand suspending thickener as the inhibiting substance samples, and fetched 5 g inhibiting substance solution into the 50 g original coal sample and mixed them around equably in the paper cup. After that, we enclosed the mixture in the insulation jar at once. The concentration and the dosage of the inhibiting substance for the prepared testing samples are shown in Table 1.

Table 1. Concentration and the dosage of the inhibiting substance

Inhibiting substance type	original coal sample weight (g)	Concentration (%)	Dosage (g)
The calcium chloride	50	20	5
The soluble glass	50	30	5
The sand suspending thickener	50	0.5	5

2.4. Experiment process

We connected the gas pathway and the temperature transmitter, then infused the dry air and checked the gas tightness. The environmental temperature was kept at 30 °C for some time until the temperature of coal sample stayed at 30 °C for minutes in the insulation jar, and then we started the temperature programmed experiment system. The speed of the airflow was 100 mL/min, and the heating rate of the temperature programmer was set as 0.8 °C/min.

3. Results and discussion

3.1. Experiment data

According to the test procedures mentioned above, we tested the coal samples treated by calcium chloride, soluble glass and the sand suspending thickener respectively, and obtained the experiment data and compared the oxidation results of treated samples with that of the original sample (Fig. 2).

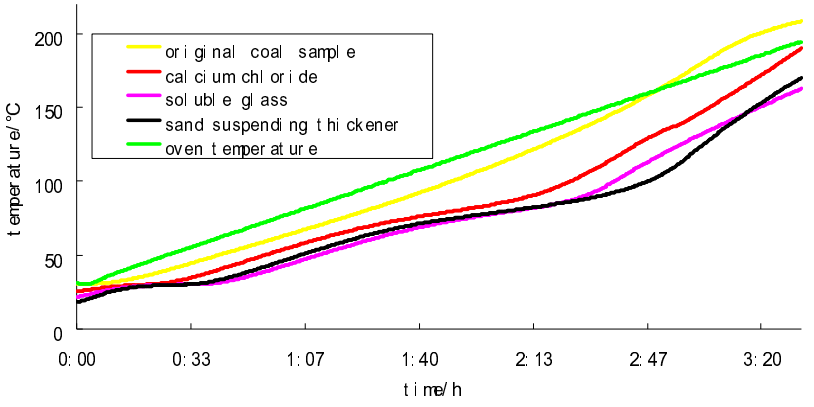

Fig. 2. Temperature upcurve of the inhibition characteristic

3.2. Analyzing the experiment data

As shown in Fig. 2, the temperature of the original coal sample in oxidation is the highest while others are lower.

And the curve tendency of the soluble glass is almost the same with the sand suspending thickener.

The inhibition efficiency at a certain temperature is defined as the ratio of the temperature difference pre- and post-treatment and the temperature of the original coal sample in a certain time, which is described as:

$$I=(T_0-T_1)/T_0\times 100\% \quad (2)$$

where, I is the inhibition efficiency, and T_0 denotes the temperature of the original coal sample in a certain time, T_1 represents the temperatures of the coal samples that are treated with inhibition substances at the same time. According to formula (2), we calculated the inhibition efficiency of the inhibition substances at different temperatures (shown in Fig. 3). As Fig. 3 indicates, the inhibition efficiency is unstable at different temperature stages.

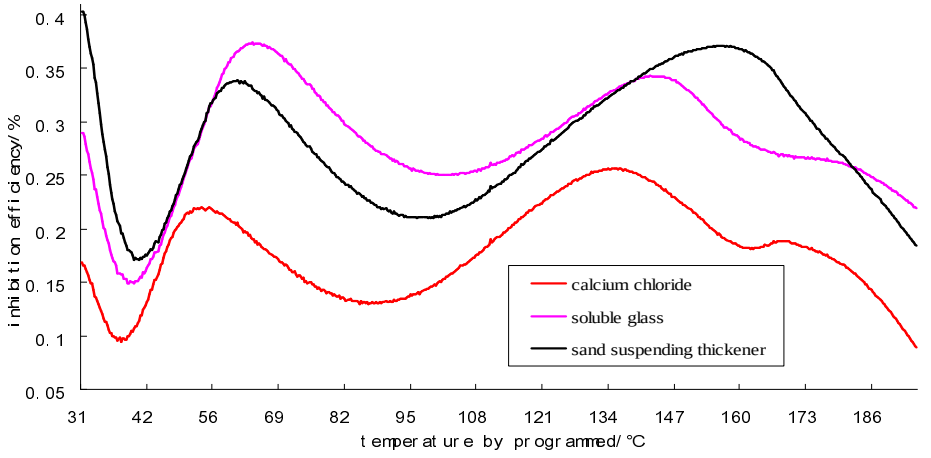

Fig. 3. Inhibition efficiency of the inhibition substances at different temperature

At the initial time, the inhibition efficiency of the sand suspending thickener drops gradually with the lowest value is 17.1% at 39.6 °C for the temperature difference between the insulation jar and the external environment; after the temperature of the environment getting stable (begin from 39.6 °C), the inhibition efficiency increases gradually due to the strong decalescence character of water of the sand suspending thickener; at the same time, the chemistry elements of the sand suspending thickener join in the free radicals chain reaction of the coal oxidation and generates a number of stable chain structures, which increases the activation energy of the chemical reaction between the active free radicals on the coal surface and the oxygen, so the reaction rate is restrained and the inhibition efficiency enhances gradually; when the temperature getting higher than 60.3 °C, the moisture of the inhibition substance vaporizes, causing the inhibition efficiency keep decreasing; at the beginning of 97.7 °C with inhibition efficiency of 21.0%, the sand suspending thickener polymer gel shapes a protecting film on the coal surface to isolate the oxygen, and the water vapour which isn't expelled from the insulation jar dilutes the oxygen concentration around the coal sample, which improves the inhibition efficiency arriving the peak of 37.1% at the temperature of 155.4 °C; with the further increase of programmed temperature, the water vapor is expelled out and the chemical structure and characteristic of the thickener are destroyed at high temperature, so the inhibition efficiency gets declined gradually. As a result of the experiments, we concluded that the sand suspending thickener can affect the inhibition characteristic during 40-160 °C, which means that the inhibition substance can inhibit the coal oxidation at low temperature.

3.3. Analyzing the inhibition mechanism of the sand suspending thickener for the coal spontaneous combustion

The sand suspending thickener has its own especial inhibiting characteristics besides the same mechanism with other inhibiting substances. As a kind of polymer gel, the sand suspending thickener is provided with great viscosity (with a maximum of 1.9 Pa·s) [5]. When it infiltrates into the coal crannies as a liquid, it covers the coal particles and creates a gel film on coal surface to isolate coal and oxygen effectively and restrain the coal spontaneous combustion. Thereby, the character of the sand suspending thickener is different from other inhibition substances

and makes an excellent inhibition characteristic.

4. Conclusions

1) The traditional testing method for the inhibition substance which tests the inhibition effect at a single constant temperature can not reflect the whole process of the inhibition for coal samples. We introduce a method of testing the inhibition characteristic based on temperature programmed system, which can display the whole process showing the trend of the inhibition and the inhibition characteristic of the inhibition substances.

2) The sand suspending thickener and the soluble glass have higher inhibition efficiency and the calcium chloride have the lowest efficiency. Besides, the inhibition substances have different efficiencies in different periods with different mechanisms. The most important inhibition phase of the inhibition substances focus on the temperature interval of 40-160 ℃ which provides the theory evidence for preventing the coal spontaneous combustion of the coal mine.

3) The sand suspending thickener, a kind of inhibition substance providing excellent inhibition characteristic, has a significant effect on the inhibition of the coal spontaneous combustion and meet requirement of fire preventing in coal mines.

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